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**SYNBAPS, Volume I:
Data Base Sources and Data Preparation.(U)**

Roger J. Van Wyckhouse

Ocean Acoustics Division
Ocean Science and Technology Laboratories

December 1978



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Foreword (U)

(U) This report is the first of a two-volume series that describes a technique by which computer software and a worldwide bathymetric data base can rapidly generate random bathymetric profiles along great-circle paths suitable for acoustic propagation model inputs.

(U) Volume I describes the origin of the bathymetric contour data utilized to create the data base and the necessary steps in the preparation of these data for primary digitization, as well as the actual digital scanning method employed.

(U) Volume II describes the techniques by which a series of computer programs transforms the raw scanned digital data into overlapping cubic spline surfaces of bathymetric data. These surfaces are placed on a random-access storage device such that rapid retrieval can be made for range-dependent model depth profiles, areal contours, or single depth points.

(U) Computer program documentation for the retrieval software are contractor-generated and would be aimed at the particular computer mainframe selected as host. Initially this would be a CDC 6600 computer system. Other computer mainframes could be documented, if warranted.

(U) Specialized subsets of the data base for application to other types of models requiring bathymetric data are easily generated. Several subsets have already been prepared and are available from the author.



SAMUEL W. MARSHALL, HEAD
OCEAN ACOUSTICS DIVISION/NORDA

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Executive Summary (U)

(U) The need for digital bathymetric data in profile form suitable for range-dependent acoustic propagation modeling gave rise to the SYNBAPS (Synthetic Bathymetric Profiling System) project. Random great-circle bathymetric profiles on a worldwide basis (where data exist) can be rapidly generated up to 10,000 nautical miles. The ability to do range-dependent, single-point depth retrieval and five-degree-square areal contours are further outgrowths of the project. This first report, in a series of two, specifically deals with the techniques of SYNBAPS data base preparation. Those techniques include approach methodology, chart selection criteria, physical construction, annotations, editing, and primary digitization or scanning.

(U) A second, unclassified report/deals with the data base's cubic spline structuring and the techniques of retrieval.

(U) Computer software documentation for the SYNBAPS retrieval programs are contractor-generated and are tailored to the data base's host computer.

(U) Except for minor maintenance, production running and the final dissemination associated with copies of the data base and retrieval software, this project is considered terminated. However, a recommendation for continued data base coverage to include at least the remaining portions of the Indian Ocean, or optimally, the southern hemisphere, is urged by researchers in earth sciences, acoustic modeling, and satellite radar altimetry.

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Acknowledgements (U)

(U) Funds for this project were provided by the Long Range Acoustic Propagation Project (LRAPP), Naval Ocean Research and Development Activity. The long-term management commitment to this project by LRAPP is appreciated, especially the high degree of interest and support shown during the successive tenures of CDR Terry J. McCloskey, CDR Vincent H. Davis, CDR James E. Paquin, and LCDR Kirk E. Evans.

(U) The efforts of Robert B. Solosko, Calspan Corporation, during the initial stages of this project, and Gil V. Jacobs, Ocean Data Systems, Inc., during the completion phases of the project, are gratefully acknowledged.

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I. INTRODUCTION (U)

(U) The Synthetic Bathymetric Profiling System (SYNBAPS) is a combination of digital computer software (programs) and a random-access storage file (presently a CDC 844 disk pack) of gridded bathymetric data, employed to rapidly generate random, great-circle (glossary) bathymetric profiles suitable for acoustic propagation modeling. SYNBAPS is completely automatic, requiring only the input, via a control card, of the latitude and longitude of the beginning and end points of a profile or the beginning point, the bearing, and the maximum range. The generated profile is available in two forms. The first is a computer-drawn profile where range in whole nautical miles is plotted against depth, in either meters, fathoms, or feet; the second is a card image file of the same data. The profile outputs in the card image file are available on magnetic tape, punched cards, or listings.

(U) A single depth point may be requested, via the same control card as used for profiles, by inputting the same latitude and longitude for both the beginning and end points. Contour plots by even five-degree-square areas are also available.

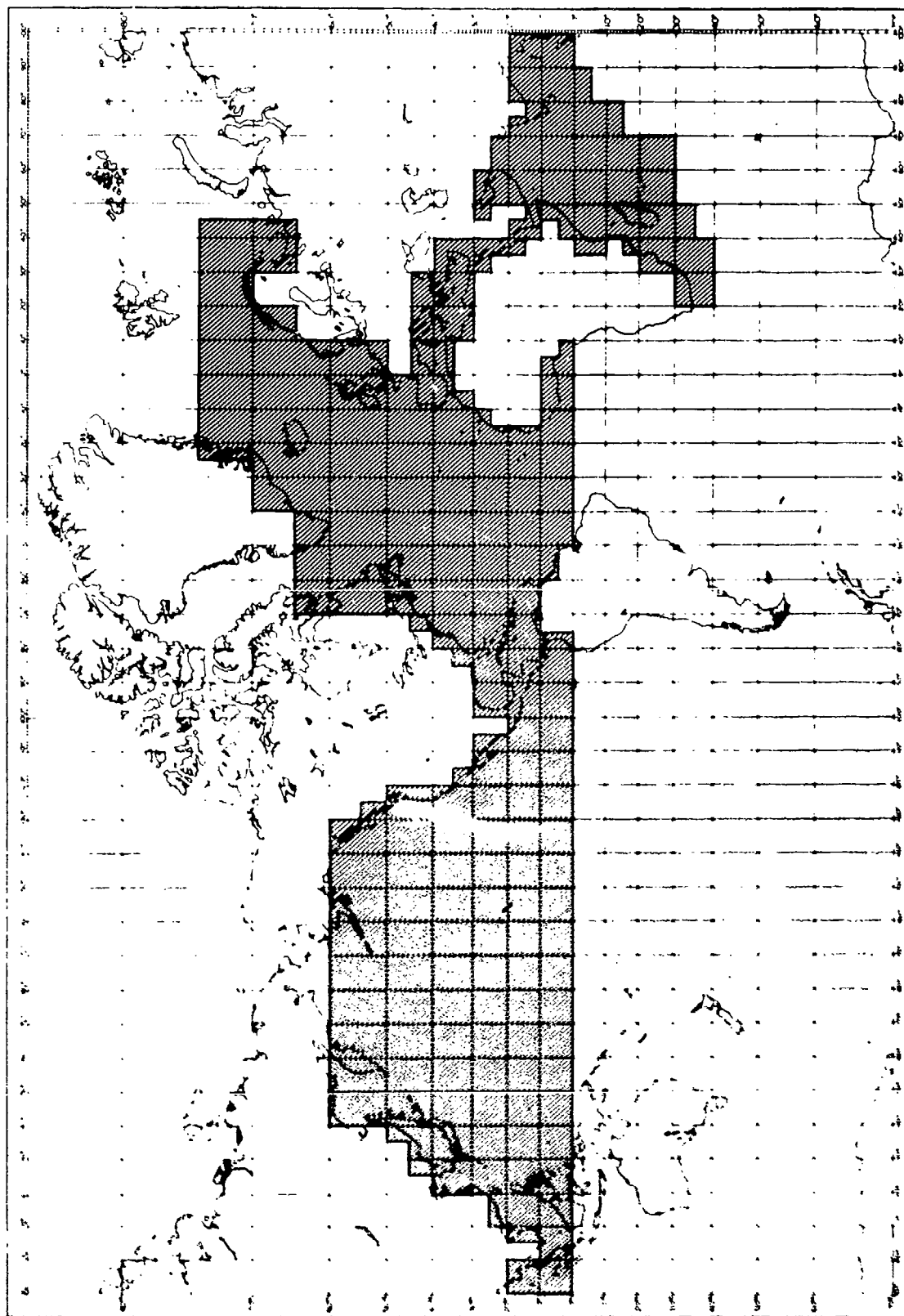
(U) The need for a computerized bathymetric data bank and techniques for rapidly manipulating large quantities of data became evident as the demand for bathymetric profiles increased and grew more urgent. It became increasingly more difficult to satisfy these demands through manual compilation of depth soundings, contouring, and profile construction. A massive recompilation and reanalysis of bathymetric data, and a systematic revision of all bathymetric charts in the North Atlantic and North Pacific Oceans (including extension of chart coverage to the equator) was recently completed and published by the Naval Oceanographic Office (1969, 1971A, 1971B, and 1975). The impracticality of using the existing official data bank of bathymetric soundings for machine generation of profiles became apparent to the modeling community. The need for a specialized bathymetric data bank to support acoustic oceanographic modeling gave rise to the development of a synthetic bathymetric profiling project using the new bathymetric contour charts and computer programs and subroutines for data storage and retrieval and for profile generation.

(U) The SYNBAPS data base was designed to meet the specific and immediate need for bathymetric profiles for acoustic modeling by providing rapid, random, great-circle retrieval in the range dependent mode. When properly used, however, the data base offers myriad applications beyond its preliminary design. The coverage of the digital data base is shown in Figure 1.

II. DATA BASE CRITERIA (U)

(U) When creating large digital data bases, it is desirable to select the best possible input data. Considering the investment in developing a digital bathymetric data base, this becomes a doubly desirable feature. To the research bathymetrist, "best possible" often means an exhaustive study of one small region of the seafloor in order to complete a contour chart or digital depth data set. While this type of research is essential, it is difficult to find coverage of this quality for an entire ocean basin or hemisphere. Alternately, all the existing digital data for a region could be assembled on a computer system for access as a digital data base. Unfortunately, most of the world-ocean bathymetric data are not in digital form, even though the situation has improved in recent years with new digital data collection and with renewed attention to the digitization of backlog data. A data base, if created from this type of unanalyzed data, would inherently be full of errors, inconsistencies and incompatibilities. These two approaches to acquiring input data for a digital bathymetric data base are both impractical and extremely costly. A more practical and cost-effective solution to this problem is to digitally scan

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(U) Figure 1. SYNAPS Coverage

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small- or medium-scale bathymetric contour charts with a uniform and cost-effective parallel tracking pattern, i.e., synthetic tracks (Davis and Kontis, 1970). If such contour charts are to be used for the creation of the SYNBAPS data base, then certain characteristics or criteria have to be established to insure the quality and coverage of the final product.

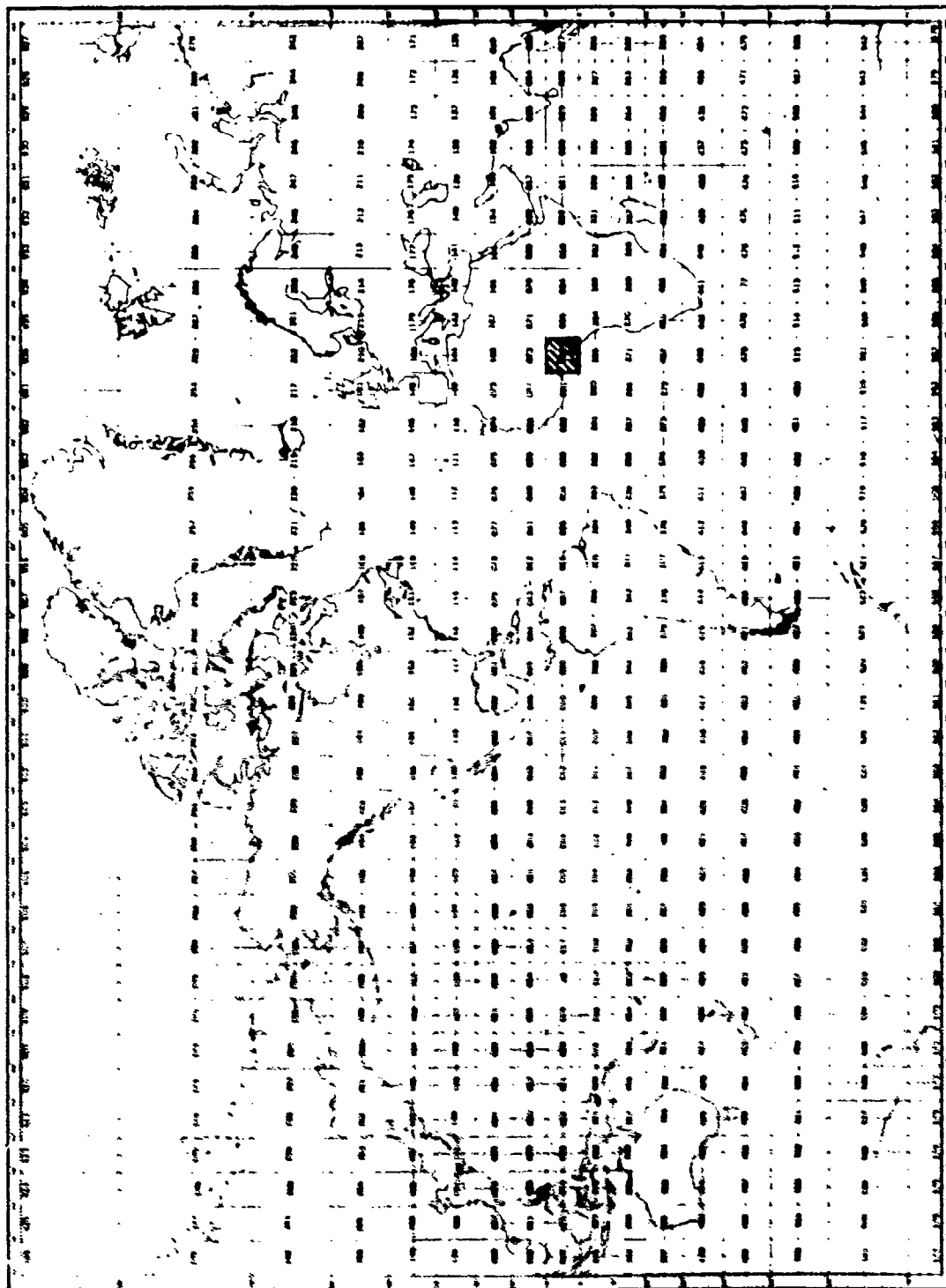
(U) Those generalized criteria developed for the SYNBAPS bathymetric contour source materials are:

- A bathymetric contour chart series or atlas covering broad ocean areas, i.e., North Pacific Ocean, North Atlantic Ocean, etc., must be utilized.
- All bathymetric contour charts should be on the same projection and scale; however, scale can be systematically different between latitudinal bands (glossary), e.g., Mercator projections (glossary).
- The chart projection should be rectangular to simplify automatic scanning of the input data (Thomas, 1964).
- All contour data should be established as either corrected or uncorrected for the actual speed of sound in seawater for either the fathom (800 fms/sec) or meter (1500 m/sec) standard.
- All series or atlas contour charts should be butt-jointed and all contours matched between charts.
- All charts used should be of large enough scale for manual annotation without costly photo enlargement, but still of photo reproducible quality should the need for enlargement or reduction arise, i.e., line weights, print size, high contrast.
- The contour coverage should be complete with no holiday (blank data) areas.
- The contour intervals should be the same for all charts in the series or atlas. The contours should be real and not form lines (glossary).
- The contour lines should not be dashed or hachured (glossary).
- The contour charts should not be cluttered with unnecessary over printed information, e.g., survey track lines, navigation information, etc.
- The charts should be available in sufficient quantity (at least five or six sets) for constructing overlap areas.
- The bathymetric contour charts or atlas should be of the most recent compilation.

III. FILE ORGANIZATION (U)

(U) The Marsden square quadrant format is the basic method within SYNBAPS by which all data are organized geographically as files for rapid data manipulation. The Marsden square system divides the earth's surface into even 100 squares (Fig. 2).

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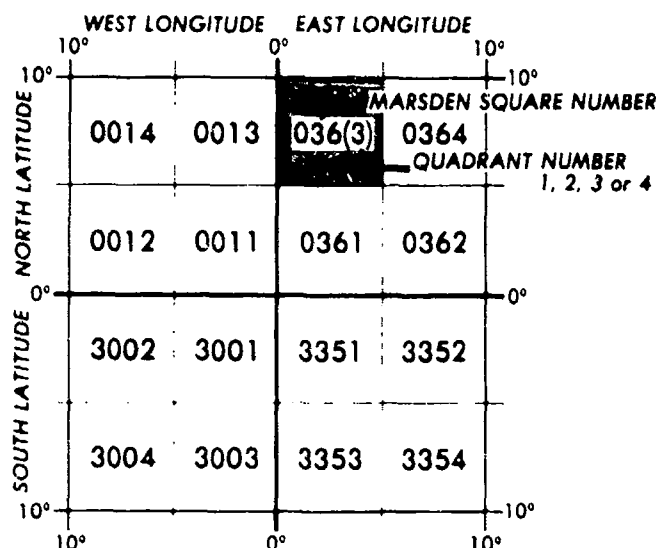
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(U) Figure 2. Marsden Square Chart

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Further subdivision of the Marsden square by quadrants is shown in Figure 3 (note that the order of quadrant numbering is dependent upon the hemisphere).



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(U) Figure 3. Marsden Square Quadrants

(U) This reference number is the Marsden square number followed by the quadrant number such that:

Marsden square number + quadrant = Marsden square quadrant

Example: 036 + 2 = 0362

The Marsden square quadrant is an unique, computer-programmable, worldwide reference to each 5° square of final gridded bathymetric data. At this stage in the processing, the Marsden square quadrant includes a 10 minute overlap on all sides.

IV. BATHYMETRIC CHART SOURCES (U)

(U) Bathymetric contour (BC) charts data at a scale of 4 in. per 1° of longitude on a Mercator projection were selected for digital scanning. The source of these charts was a set of atlases prepared by Scripps Institution of Oceanography (SIO) for the North Pacific Ocean (Naval Oceanographic Office, 1969, 1971A, and 1971B).

With only minor exceptions, these charts met the SYNAPS criteria delineated in the section on data base criteria. These charts were contoured at an uncorrected 200 fathom (fm) interval.

(C) Unpublished classified BC charts prepared by the Bathymetric Division, Naval Oceanographic Office, and Van Wyckhouse (1975) were selected because of their superior quality as alternate source material in the North Pacific Ocean for 23 Marsden square quadrants. Figure 4 shows where the classified contour data supersede the SIO data. In all cases, the contour data from the classified BC charts are

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butt-matched to the surrounding unclassified data. Table 1 contains a listing of the then-unpublished classified BC charts, parts of which were utilized to augment the SIO contours and are now published by the Defense Mapping Agency Hydrographic/Topographic Center (DMAHTC). The SYNAPS process of scanning classified contours is the same technique by which classified contours have been sanitized manually into unclassified data for years, only now the process is automated (Appendix A). Those BC charts prepared by Van Wyckhouse (1975) were constructed by utilizing contour selection overlays (glossary) at a 200 fm interval at the 1: scale, thereby sanitizing the classified data.

(U) Table 1. Classified BC Charts Used in the North Pacific Ocean

<u>Chart No.</u>	<u>Edition</u>	<u>Date</u>	<u>Classification</u>	<u>Available</u>
BC 2106	First	04/75	Confidential	DMAHTC
BC 2203	First	10/75	Confidential	DMAHTC
BC 2204	First	06/75	Confidential	DMAHTC
BC 2205	First	04/75	Confidential	DMAHTC
BC 2206	First	05/75	Confidential	DMAHTC
BC 2207	First	05/75	Confidential	DMAHTC
BC 2303	First	09/75	Confidential	DMAHTC
BC 2304	Second	11/72	Confidential	DMAHTC
BC 2305	First	06/75	Confidential	DMAHTC
BC 2306	First	10/75	Confidential	DMAHTC

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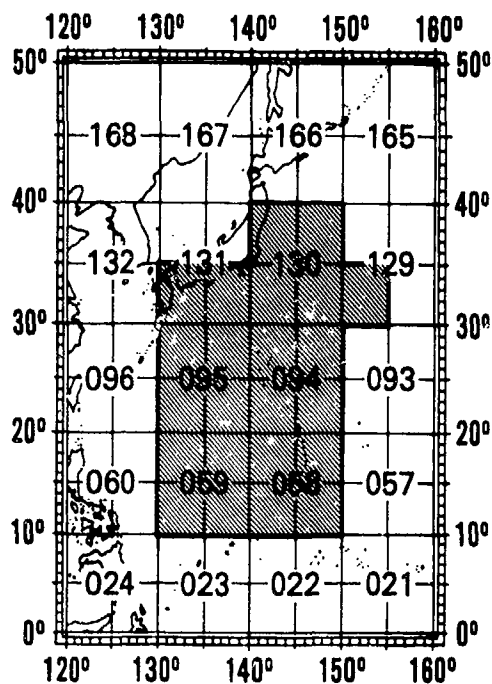
(U) Bathymetric contour charts covering the North Atlantic Ocean and adjacent seas, including the Mediterranean Sea, were found in the classified Naval Oceanographic Office's Special Publication NOO-SP-1304 (1975). Like the North Pacific Ocean source material, this atlas was produced from BC charts at full scale, then photo-reduced and published in atlas format. Therefore, source materials were readily available at 4 in. to 1° of longitude on a Mercator projection. However, these data were contoured at an uncorrected 200 meter interval.

(U) Figure 5 shows the location of the classified Marsden square quadrants in the North Atlantic Ocean. Both Figures 4 and 5 refer to the location of classified data in the Marsden square quadrant format. Standard BC charts usually display a much larger area than the quadrant format (Table 2). Therefore, the quadrant format may reflect only those specific regions within a BC chart that actually contain classified contour data. The quadrant contour charts prepared for digitizing were the only actual classified material in this project. The resultant digital magnetic tape and the final gridded data are unclassified via the procedure used (Appendix A). They have thus been sanitized to unclassified and comply with OPNAV INSTRUCTION 5030.10 of Naval Operations, 1971. This methodology was unofficially reviewed by both the Naval Oceanographic Office and the Defense Mapping Agency and found acceptable.

(U) Supplemental unclassified chart sources from the Naval Oceanographic Office allowed the data base to be extended into the North Atlantic Ocean to 74°N, as the atlas charts provided coverage only to 74°N.

(U) Source material for the Indian Ocean was obtained from the Naval Oceanographic Office from their Indian Ocean regional charting project in uncorrected meters. Fortunately, these project charts were available at the BC chart scale, contour interval, etc., and are on Mercator projection, thus fitting the defined

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(C) Figure 4. Classified Data in the North Pacific

(U) Table 2. Standard Latitudinal Bands for BC Charts

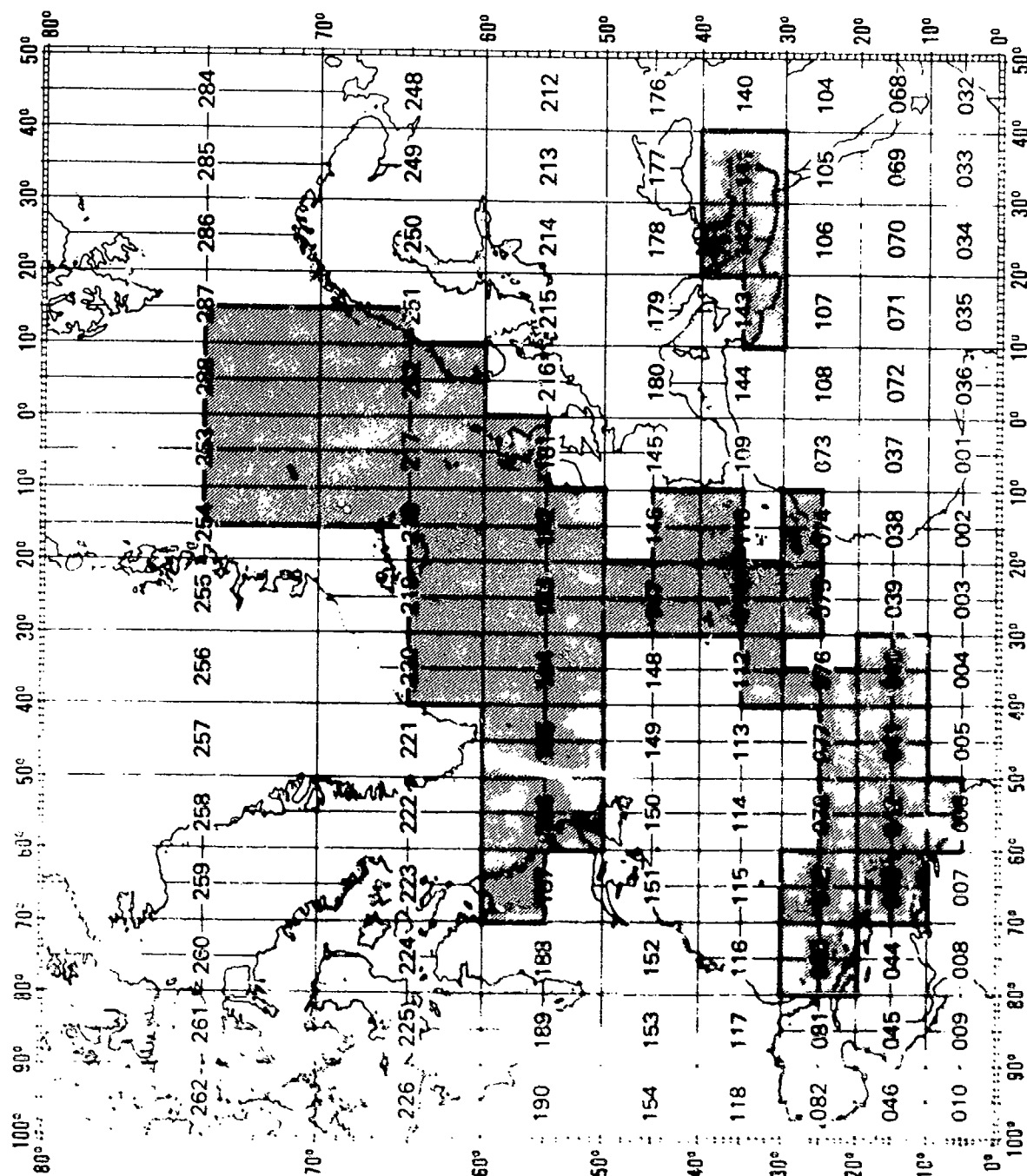
<u>N. Hemisphere</u>	<u>S. Hemisphere</u>
3°S - 3°N	3°S - 10°S
3°N - 10°N	10°S - 17°S
10°N - 17°N	17°S - 23°S
17°N - 23°N	23°S - 29°S
23°N - 29°N	29°S - 35°S
29°N - 35°N	35°S - 40°S
35°N - 40°N	40°S - 45°S
40°N - 45°N	45°S - 49°S
45°N - 49°N	49°S - 53°S
49°N - 53°N	53°S - 56°S
53°N - 56°N	56°S - 59°S
56°N - 59°N	59°S - 62°S
59°N - 62°N	62°S - 64°S
62°N - 64°N	64°S - 70°S
64°N - 70°N	70°S - 74°S
74°N - 77°N	74°S - 77°S

NOTE: All standard BC charts cover 10° of longitude.

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(U) Figure 5. Classified Data in the North Atlantic

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chart criteria well. Full coverage for the Indian Ocean was not available during the chart scanning process; therefore, Figure 1 reflects only those Marsden square quadrants where data were obtainable at the time. There were no classified data utilized in the Indian Ocean.

(U) The fact that the North Pacific Ocean source materials are in uncorrected fathoms and the North Atlantic and Indian Ocean sources are in uncorrected meters poses no problem, since the final data base is in meters at the uncorrected standard of 1500 m/sec. Because sound speed in sea water varies considerably with depth, all depth recorders are standardized to collect data at a single assumed fathom or meter standard speed of sound. The fathom standard is established to be 800 fms/sec; to convert this to meters per second, multiply 800 fms/sec by the number of meters in 1 fm or 1.8288 m/fms, which will yield 1463.04 m/sec. However, the metric standard is established at 1500 m/sec; therefore, to find what 1 fm is worth under the metric standard, divide the meter standard by the fathom standard, which yields 1.875 m/fms. To convert fathom standard depths to meter standard depths, multiply the fathom depths by 1.875 m/fms to get the depths in uncorrected meters. This applies to only bathymetry collected as uncorrected for the speed of sound in sea water. All corrected fathom bathymetry would be multiplied by 1.8288 m/fms.

V. CHART PREPARATION FOR SCANNING (U)

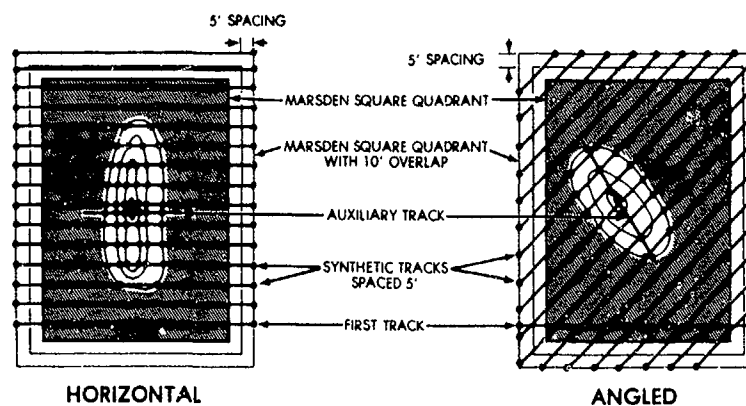
(U) The primary scanning direction selected for SYNBAPS is a parallel west-to-east line, with five minutes of latitude separation superimposed on the bathymetric contours. A data point is achieved when this pattern of synthetic track lines intersects a contour line. Clearly, best resolution is obtained with such a scheme when the track lines are perpendicular to the contour lines. Therefore, a secondary tracking direction with a similar pattern is used from near-horizontal to near-vertical when contoured features have an east-west trend. The angled tracking is done to increase the number of data contacts (Fig. 6).

(U) Auxiliary tracks are used to retain the maximum amount of data for topographic peaks and depressions not falling on a primary or secondary tracking pattern (Fig. 6). Because of difficult data point differentiation in the longitudinal plane, these auxiliary tracks are best made horizontally or at a shallow angle to the horizontal where precision can be maintained.

(U) The Marsden square quadrant contour charts, as physically constructed for digital scanning, are assembled by starting with the basic Marsden square quadrant area made up from individual BC charts. To this is added 10 minutes of overlapping contour information from each of the contiguous quadrants. It is also necessary to include sufficient space on these 10-minute strips to allow border annotation. All of these pieces of the BC chart are carefully glued together.

(U) The newly assembled charts are annotated along the boundary with latitude/longitude and Marsden square quadrant number. The depth information is added for the start and end points of each track, dependent upon which pattern of synthetic tracks is to be used, by visual interpolation. Next, the bathymetrist indicates where auxiliary tracks are to be scanned by drawing a short line through the topographic feature (Fig. 6). It may be necessary to extend the auxiliary track line through several nonslope contours to terminate the eventual interpolation for the eastern end point. Because most bathymetric interpolation schemes do not like flat areas (no slope), then at every major feature along a track line where two contiguous data contacts of equal depth value occur, some form of supplemental data is desirable. Usually this is done to separate only the significant features on the

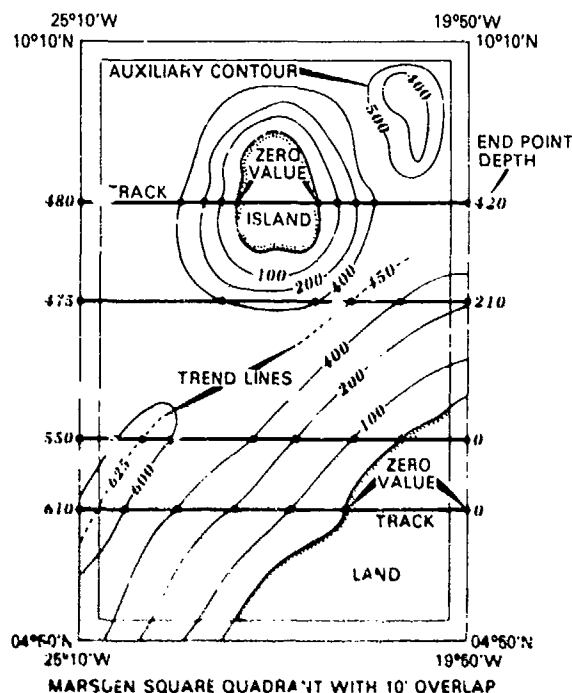
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(U) Figure 6. Examples of Synthetic Track Orientation

contour chart (Fig. 7). This supplemental data can take the form of inserted points, auxiliary contour lines, or short contour-valued trend lines. Additionally, it may be necessary for the bathymetrists to draw in contours for any "no data" areas. This type of contouring is often based upon regional trend, other topographic features in the region, and such supplemental geophysical data as magnetics or gravity.



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(U) Figure 7. Examples of Annotations Showing Only a Representative Number of Tracks

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(U) It should be noted, with reference to Figure 1, that some very shallow ocean quadrants along coastlines were omitted from the data base. This was done to minimize the expense of data scanning and processing, in addition to keeping the data base as small as possible. These regions are much less than 100 fm or 200 m, and usually are at the head of enclosed bays or inlets. The Black Sea portion of Marsden square quadrant 1782, the Aegean Sea, was left blank (actually shown as land) because the remaining parts of the Black Sea are not included in the data base.

(U) Almost all of the Marsden square quadrant charts used in the scanning process were physically prepared by the Bathymetry Division, Naval Oceanographic Office. Exceptions are the classified portions of the North Pacific Ocean, two test quadrants prepared by the author, and four quadrants in the Baffin Bay that were prepared by Ocean Data Systems, Inc. (ODSI).

VI. BATHYMETRIC CONTOUR CHART DIGITIZATION (U)

(U) After final editing, these charts are usually batched in groups of 20 to 50 charts for the scanning process. The initial technique of scanning or digitization process (described in Van Wyckhouse, 1973), was effective, but very slow in operation. Thus, a faster method for production processing was sought. It was essential that this method be fast, but still retain good quality control. The Calspan Corporation (then Cornell Aeronautical Laboratory, Inc.) of Buffalo, New York, was selected to develop the faster technique and perform the production processing. This project was placed under the direction of Dr. Robert B. Solosko, utilizing the facilities of Calspan's Image Processing Laboratory. A comprehensive description of the Calspan methodology of chart digitization is given in Solosko (1976). Appendix A is a brief description of the Calspan technique and was drawn from Solosko (1976), Solosko (1973), Cornell Aeronautical Laboratory (1971), and several proposal documents. Patents were applied for by Calspan for several of the more interesting aspects concerning their technique.

(U) The Calspan facility has been dismantled and any further scanning of contour data will have to be accomplished elsewhere. An intriguing approach would be to input and process digitized, video-scanned contour data in real-time at standard TV scan and frame rates directly to an array processor-controlled by a host mini-computer. After these data are stored, then the process of going through a menu of steps to identify and extract data to be retained as digital outputs is performed. This extraction phase is similar to the Calspan technique.

(U) The products from the Calspan digitization were 15 magnetic tapes of synthetic track line data derived from scanning the Marsden square quadrant bathymetric contour charts. During the subsequent processing of these data, 19 Marsden square quadrants (out of 687) were found to contain enough errors to warrant redigitization. Twelve quadrants were rescanned by Calspan and even were manually redigitized by ODSI. In addition, ODSI began scanning four quadrants in the North Atlantic that had been originally excluded from the data base. Further details for this subsequent processing phase are discussed in Jacobs (1977) and in Van Wyckhouse (1979).

(U) Unfortunately, the angled tracking pattern lead to numerous problems when translated to production processing. These problems centered around the splitting of the quadrant charts into four sections during angled scanning, thus producing redundant data points when the four sections were reassembled for processing. Additionally, data points on the angled scans could not be resolved to the same precision as those on a horizontal scan, thus creating data points with the same longitude. Both of these conditions would cause the structuring computer program to

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abort. Twelve of the 19 quadrants that required redigitizing were originally scanned with an angled tracking pattern. Consequently, midway through the processing phase after approximately 60 quadrants were scanned with the angled tracking pattern, the angled tracking pattern was discontinued. Errors not associated with the tracking pattern were related to poor accuracy due to improper registration.

VII. SUMMARY AND RECOMMENDATIONS (U)

(U) In developing a workable data base for SYNBAPS, it was apparent that properly screening the existing bathymetric contour charts, would be the only means of achieving quality control. With this established, it was then necessary to develop an efficient means of digitizing the contour data. The Calspan chart scanning technique and subsequent production digitizing was fostered and utilized. Their technique resulted in only a 2.8% failure rate. Failure, here, means that so many errors were created, that in the author's judgment, it was more cost-effective to redigitize than to continue making corrections. The remaining quadrants had an error rate of only 1%, some of which were related to the addition of zero fill land data, and were not Calspan's responsibility. Such errors should not detract from the large volume of good data derived from this scanning technique.

(U) Errors were, in many cases, directly traceable to failure of the annotations to convey proper information to the scanner, because of either erroneous annotations or incompleteness. For example, more odd-numbered contours in the form of trend lines between equal valued, even contoured lines would have been helpful.

(U) It is recommended that the remaining region of the Indian Ocean be included in the data base, as sufficient source material now exists to cover at least to 40°S and to 140°E. This range would encompass about 94 Marsden square quadrants.

(U) In view of needs expressed by researchers in earth sciences, acoustic modeling, and satellite radar altimetry for additional SYNBAPS coverage in the southern hemisphere, it is recommended that bathymetric contour charts or data already digitally scanned be collected for processing into the data base.

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Glossary of Selected Terms (U)

ACCURACY: The degree of freedom from error, that is, the degree of conformity to truth or to a rule. Accuracy is contrasted with precision, e.g., four-place numerals are less precise than six-place numerals; nevertheless, a properly computed four-place numeral might be more accurate than an improperly computed six-place numeral.

ALGORITHM: A finite set of rules that gives a sequence of operations for solving a specific type of problem. It should have the following features: (1) finiteness, (2) definiteness, (3) input, (4) output, and (5) effectiveness.

BAND (LATITUDINAL BAND): Any latitudinal strip, designated by accepted units of linear or angular measurement, which circumscribes the earth.

BATHYMETRIC: Relating to the measurement of ocean depths.

BATHYMETRIC CHARTS: A topographic map of the ocean floor.

BATHYMETRY: The science of determining and interpreting ocean depths and topography.

BEARING: 1. (General) The horizontal angle at a given point measured clockwise from a specific reference datum to a second point. Also called bearing angle.
2. (Navigational) The horizontal direction of one terrestrial point from another, expressed as the angular distance from a reference direction. It is usually measured from 000° at the reference direction clockwise through 360°. The terms, bearing and azimuth, are sometimes used interchangeably, but in navigation, the former customarily applies to terrestrial objects and the latter to the direction of a point on the celestial sphere from a point on the earth.

BINARY CODED DECIMAL (BCD): Pertaining to a decimal notation in which the individual decimal digits are each represented by a group of binary digits; e.g., in the 8-4-2-1 binary coded decimal notation, the number 23 is represented as 0010 0011, whereas in binary notation, 23 is represented as 10111.

BLOCK: A set of things, such as words, characters, or digits, that are handled as a unit.

BLOCK DIAGRAM: A diagram of a system, instrument, computer, or program in which selected portions are represented by annotated boxes and interconnecting lines.

DATA: Any representations, such as characters or analog quantities, to which meaning might be assigned.

DIGITIZE: 1. The conversion of graphical analog information or characters into digital form, usually for the purpose of rapid manipulation or storage by a digital computer. 2. To express data in a digital form.

FILE: A collection of related records treated as a unit. Thus, in inventory control, one line of an invoice forms a record, and the complete set of such records forms a file.

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FORM LINES: Dashed lines resembling contours, but representing no actual elevations, that have been sketched from visual observation or from inadequate or unreliable map sources to show collectively the shape of the terrain rather than the elevation.

GREAT CIRCLE: A circle on the surface of the earth, the plane of which passes through the center of the earth.

HACHURES: A method of portraying relief by short, wedge-shaped marks radiating from high elevations and following the direction of slope to the lowland.

INTERPOLATION: To determine intermediate values between given fixed values. As applied to logical contouring, to interpolate is to ratio vertical distances between given spot elevations.

MARSDEN CHART: A system introduced by Marsden early in the nineteenth century for showing the distribution of meteorological data on a chart, especially over the oceans. A Mercator map projection is used; the world between 90°N and 80°S is divided into Marsden "squares," each square is 10° latitude by 10° longitude. These squares are systematically numbered to indicate position. Each square may be divided into quarter squares or into 100 one-degree subsquares numbered from 00 to 99 to give the position to the nearest degree.

MERCATOR PROJECTIONS: A conformal map projection of the cylindrical type. The equator is represented by a straight line true to scale; the geographic meridians are represented by parallel straight lines perpendicular to the line representing the equator, and are spaced according to their distance apart at the equator. Geographic parallels are represented by a second system of straight lines perpendicular to the family of lines representing the meridians and are therefore parallel with the equator. Conformability is achieved by mathematical analysis, the spacing of the parallels being increased with increasing distance from the equator to conform with the expanding scale along the parallels resulting from the meridians being represented by parallel lines. Also called equatorial cylindrical orthomorphic map projection.

MERIDIONAL PART: The length of the arc of a meridian between the equator and a given parallel on a Mercator chart, expressed in units of one minute of longitude at the equator.

PRECISION: The degree of discrimination with which a quantity is stated; e.g., a three-digit numeral discriminates among 1000 possibilities.

PROFILE: A vertical section of the surface of the ground, or of underlying strata, or both, along any fixed line.

RANDOM ACCESS: 1. Pertaining to the process of obtaining data from, or placing data into, storage where the time required for such access is independent of the location of the data most recently obtained or placed in storage. 2. Pertaining to a storage device in which the access time is effectively independent of the location of the data.

SELECTION OVERLAY: A tracing of selected map source detail compiled on transparent material; usually described by the name of the features or details depicted, such as contour overlay or vegetation overlay. Also called lift, pull up, or trace.

SYNTHETIC: Produced artificially; devised, arranged, or fabricated for special situations to imitate or replace usual realities.

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(U) Appendix A. Description of the Bathymetric Chart Digitizing Facility

EQUIPMENT

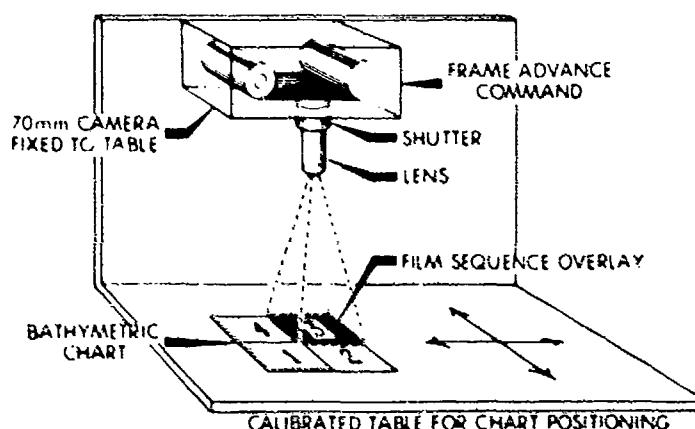
(U) The chart encoding facility utilizes a flying spot scanner, a PDP-9 computer, a digital image display, a keyboard terminal, and a track ball.

(U) The flying spot scanner scans a 2.5 in² area in an array of 1024 by 1024 points. Each point in the image field in the scanner is defined by one of 64 values, depending on the gray level of the image under the spot. The scanner is random addressable; thus, selected area or patterns of the image can be scanned. For use in Calspan's flying spot scanner, the bathymetric contour charts are divided into four sections and each section is photographed onto 70 mm film. The film is read by a back-and-forth sweeping action in the scanner. The PDP-9 computer is used for general computation and control. The track ball is used to move the cursor on the digital image display, thereby allowing the operator to select specific points on the image for processing. The cursor may also be controlled by the PDP-9 computer independently of the track ball. The keyboard terminal, which includes an LED alphanumeric display, is used to provide the operator with instructions and information and for entering depth and coordinate information.

PROCESSING

(U) The process for digitizing the bathymetry charts uses an interactive approach which makes the best use of the computer's speed and the operator's judgment. Most of the digitizing process is performed automatically by the computer. The operator is required only to resolve ambiguities in areas of high densities of contour lines, and to enter contour lines and some contour depth information.

(U) To provide for scanning of bathymetric charts on Calspan's flying spot scanner, each chart is subdivided into four sections and photographed onto 70 mm film (Fig. 8). Initially, the film image of each section of the chart is scanned by



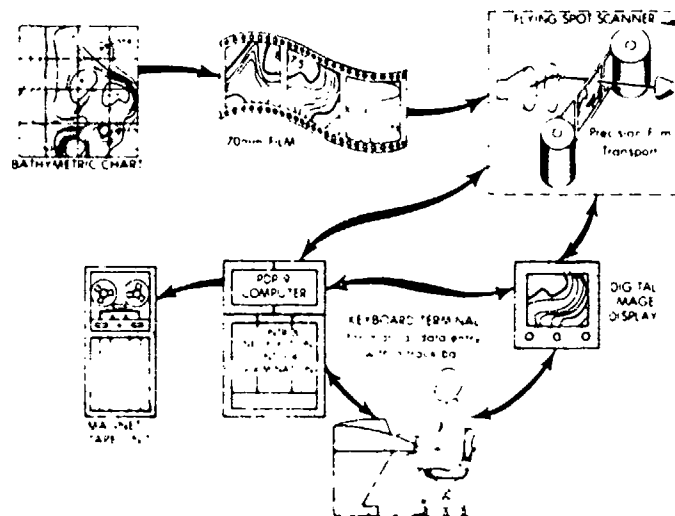
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(U) Figure 8. Functional Diagram of a 70 mm Precision Camera Fixed to a Calibrated Table for Bathymetric Chart Segmentation, Reduction, and Photographic Storage.

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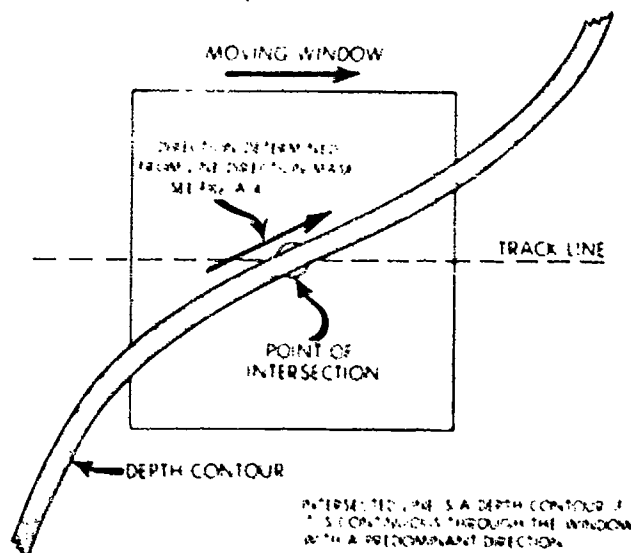
the flying spot scanner to produce a digitally sampled image. This digital image is then displayed for the operator on a digital storage oscilloscope and TV-type monitor. By using a track ball device to move a cursor on the chart image, the operator can indicate the locations of the chart coordinate axes. This system is designed to handle the coordinate non-linearities inherent in Mercator projection charts. It also has the capability of handling charts that might have been rotated slightly during the photographic process; that is, charts for which the chart coordinate axes do not line up with the scanner coordinate axes. A system functional block diagram is shown in Figure 9.



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(U) Figure 9. Bathymetric Chart Digitizing Functional Block Diagram

(U) After the entry of the coordinate calibration information and other pertinent data, this system computes the end points of all the normal parallel track lines. The locations of these track lines are displayed for the operator over the image of the bathymetry chart. The chart is then rescanned along each track line and the contours that cross the track line are indicated to the operator on the displayed image. The process for detecting contour intersections utilizes a moving window that samples the chart image in a small region around each point on the track line (Fig. 10). That is, the position of the window moves along the track line, and at each position, various tests are performed on the chart image within the window

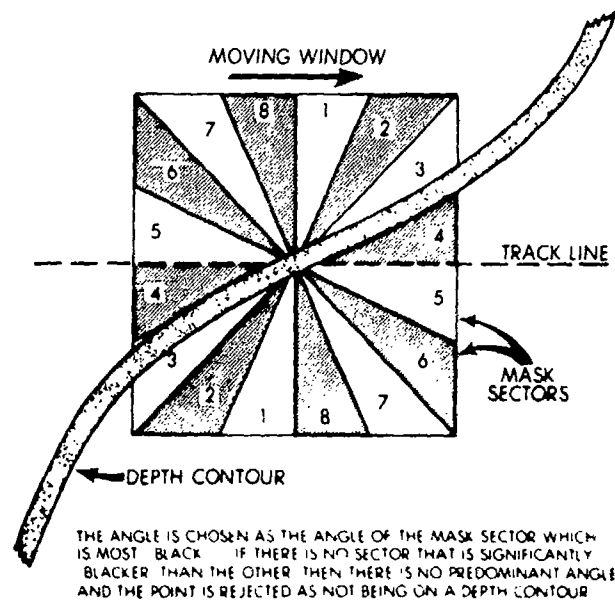


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(U) Figure 10. Scanning Window

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to determine if a contour passes through the window center. These tests include the determination of the image density in the window center, the continuity of a line passing through center of the window, and the direction and quality of a contour line passing through the center of the window (Fig. 11). In this way, "clean" contours are discriminated from detections on tic-marks and small or large characters.



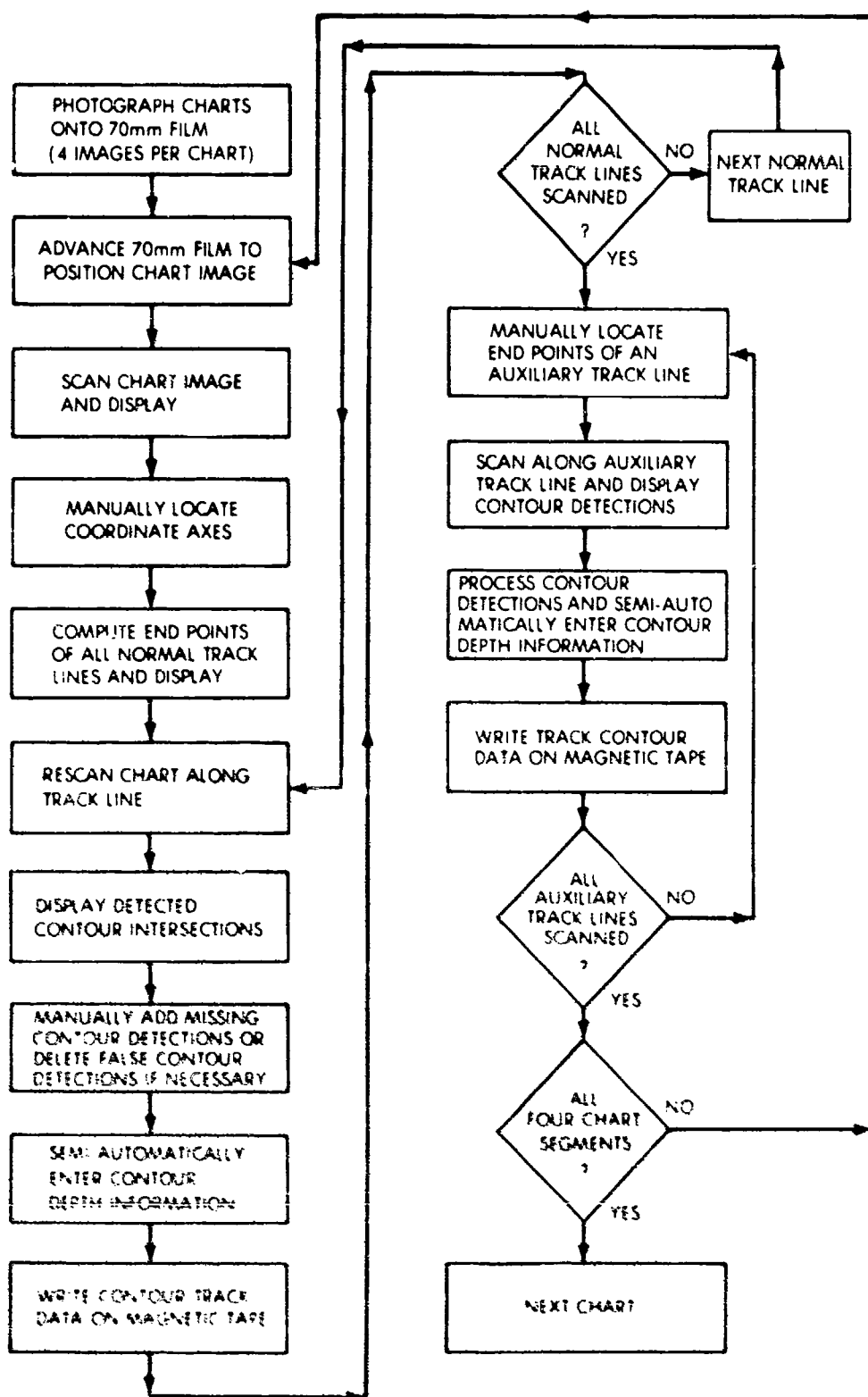
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(U) Figure 11. Contour Angle Determined Using a Line Direction Mask

(U) After each track line is scanned and the detected contours are displayed for the operator, the operator has several options that can be used for entry of the correct depth information. For the first track line scanned, the operator is required to enter the depth information manually for each contour detection. This process is simplified because of the standard increments and decrements in the depth for adjacent contours. Thus, the operator need only enter the depth for one contour detection and indicate for each adjacent contour detection whether it is a standard increment or decrement from the previous depth entered. If a contour detection was missed or if a point is erroneously flagged as a contour detection, the operator may either add or delete detections from the track line. The operator also has the option of entering the depth for several contour detections on the track line and the system will automatically interpolate the depth information for the contour detections in between. After the depth information for the first track line is entered, subsequent entry of the depth information for the remaining track lines is mainly an automatic process. A contour detection is followed back to a previous detection of the same contour from a previous track line for which the depth information has already been entered. Thus, the required amount of operator interaction is minimal. The depth information for all contour detections is sequentially displayed so that the operator can correct errors as they occur.

(U) After the normal parallel track lines have been scanned and the depth information for these are entered, the operator may initiate the scanning on auxiliary track lines as necessary. Most of the options available for entering depth information on the normal track lines are also available for entering depth information on the auxiliary track lines. Figure 12 is a system flow diagram for chart digitization.

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() Figure 1. Flow Diagram of the Process for Digitizing Bathymetric Charts.

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(U) In addition to the manual error checking performed by the operator, the system monitors the consistency of the depth information from adjacent contour detections. If an inconsistency is detected, the situation is indicated to the operator for correction.

(U) This digitizing process is repeated for each of the four sections comprising each Marsden square quadrant chart of bathymetric contours. The four sections of the Marsden square quadrant chart are numbered 1, 2, 3 and 4, starting in the lower left-hand section and proceeding counterclockwise. This numbering method is maintained in the magnetic tape data. The result of this digitizing process provides the coordinates (in the chart coordinate system) and the depth information on magnetic tape for each of the intersections of the contours with the track lines.

(U) The contour depth data in fathoms for the North Pacific Ocean and meters elsewhere are written on magnetic tape, with each track line beginning a new physical record. All data from one Marsden square quadrant chart is contained in a single file. The data record for each track line includes a header that contains the chart identification number, date, track number, etc. The header information is contained in a separate record that precedes the longitude, latitude, and depth information for a single track. The eighth word of the header record contains the number of logical records which contain information for a specific track. The tape is written at a 556 bpi, 7 track, BCD (glossary) tape with even parity. The records are blocked in groups of 2080 bytes. Each physical record contains 26 logical records that are 80 bytes (6 bits = 1 byte) in length.

(U) The information contained in the header and the number of characters allotted for each word is shown in Table 3.

(U) Table 3. Header Characters

<u>Information</u>	<u>Characters</u>
Marsden square quadrant	4
Date	6
Section number (1 through 4)	1
Auxiliary flag (0 for normal track, 1 for auxiliary track)	1
Partial digitization flag (0 for complete chart, 1 for partial chart, land area excluded)	1
Track line number	3
Number of detections in track line	3
Number of 80-byte records written on tape for this track line	3
.	1
0	1
TOTAL:	$\frac{1}{24}$

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When the chart identification number becomes zero, this indicates the end of data for the chart. Because physical record for the track may extend past this number, it should be ignored.

Each of the logical records contains the longitude, latitude, and depth information from four detections, and is followed by 8 blank characters. The format for each of these items is given in Table 4.

(U) Table 4. Data Characters

<u>Information</u>	<u>Format</u>	<u>Characters</u>
Longitude	S999.999 (A1, F6.3)	7
Latitude	S999.999 (A1, F6.3)	7
Depth	9999 (F4.0)	<u>4</u>

TOTAL: 18

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The letter "S" represents the sign character. When the sign character has an alphanumeric value of N, that particular coordinate is negative. When the sign character equals P, that coordinate is positive. In the method used throughout this report, south and west are always negative and north and east are always positive.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) (U) The need for digital bathymetric data in profile form suitable for range-dependent acoustic propagation modeling gave rise to the SYNBAPS (Synthetic Bathymetric Profiling System) project. Random great-circle bathymetric profiles on a worldwide basis (where data exist) can be rapidly generated up to 10,000 nautical miles. The ability to do range-dependent, single-point depth retrieval and five-degree-square areal contours are further outgrowths of the project. This first report, in a series of two, specifically deals with		

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the techniques of SYNBAPS data base preparation. Those techniques include approach methodology, chart selection criteria, physical construction, annotations, editing, and primary digitization or scanning.

(U) A second, unclassified report deals with the data base's cubic spline structuring and the techniques of retrieval.

(U) Computer software documentation for the SYNBAPS retrieval programs are contractor-generated and are tailored to the data base's host computer.

(U) Except for minor maintenance, production running and the final dissemination associated with copies of the data base and retrieval software, this project is considered terminated. However, a recommendation for continued data base coverage to include at least the remaining portions of the Indian Ocean, or optimumly, the southern hemisphere, is urged by researchers in earth sciences, acoustic modeling, and satellite radar altimetry.

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